

What is claimed is:

1. A filtering face mask that comprises:

(a) a mask body that is adapted to fit at least over the nose and mouth of a  
5 wearer to create an interior gas space when worn; and

(b) an exhalation valve that is in fluid communication with the interior gas space, the exhalation valve comprising:

(i) a valve seat that comprises a seal surface and an orifice through which exhaled air may pass to leave the interior gas space; and

10 (ii) a flexible flap that is mounted to the valve seat such that the flap makes contact with the seal surface when the valve is in its closed position and such that the flap can flex away from the seal surface during an exhalation to allow exhaled air to pass through the orifice to ultimately enter an exterior gas space, the flexible flap comprising at least first and second juxtaposed layers, wherein at least one of the layers is stiffer than the other.

15 2. The filtering face mask of claim 1, wherein the first and second layers comprise first and second materials, respectively, that each have a different modulus of elasticity.

20 3. The filtering face mask of claim 2, wherein the first layer is disposed closer to the seal surface than the second layer when the flap is positioned against the seal surface, and wherein the second layer has a greater modulus of elasticity than the first layer.

25 4. The filtering face mask of claim 3, wherein the first layer contacts the seal surface when the flap is positioned against the seal surface.

30 5. The filtering face mask of claim 1, wherein the exhalation valve is mounted to the mask body.

6. The filtering face mask of claim 1, which is a negative pressure half-mask that has a fluid-permeable mask body that contains a layer of filter material.

7. The filtering face mask of claim 1, wherein the exhalation valve is a  
5 flapper-style exhalation valve.

8. The filtering face mask of claim 7, wherein the flapper-style exhalation valve has a planar seal surface.

10 9. The filtering face mask of claim 8, wherein the flexible flap is not pressed against the seal surface under neutral conditions.

15 10. The filtering face mask of claim 1, wherein the exhalation valve is in the form of a button-style valve.

11. The filtering face mask of claim 1, wherein the flexible flap includes a third layer that has substantially the same stiffness as the first layer.

20 12. The filtering face mask of claim 11, wherein the flexible flap exhibits symmetry with respect to the second layer, and wherein the second layer is stiffer than the first and third layers.

25 13. The filtering face mask of claim 1, wherein the second layer has a modulus of elasticity that is greater than the first layer, and wherein the first layer contacts the seal surface when the flap is positioned against the seal surface.

14. The filtering face mask of claim 13, wherein the modulus of elasticity of the first layer is preferably about 0.15 to 10 megaPascals, and wherein the modulus of elasticity of the second layer is about  $2$  to  $1.1 \times 10^6$  megaPascals.

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15. The filtering face mask of claim 13, wherein the modulus of elasticity of the first layer is preferably about 1 to 7 megapascals, and wherein the modulus of elasticity of the second layer is about 200 to 11,000 megaPascals.

5 16. The filtering face mask of claim 15, wherein the second layer has a modulus of elasticity of 300 to 5000 megaPascals.

10 17. The filtering face mask of claim 1, wherein the second layer is stiffer than the first layer, and wherein the moduli ratio between the first layer and the second layer is less than 1.

15 18. The filtering face mask of claim 1, wherein the second layer is stiffer than the first layer, and wherein the moduli ratio between the first layer and the second layer is less than 0.01.

19. The filtering face mask of claim 1, wherein the second layer is stiffer than the first layer, and wherein the moduli ratio between the first layer and the second layer is less than 0.001.

20 20. The filtering face mask of claim 3, wherein the flexible flap has a thickness of about 10 to 2,000  $\mu\text{m}$ .

21. The filtering face mask of claim 3, wherein the flexible flap has a thickness of about 20 to 700  $\mu\text{m}$ .

25 22. The filtering face mask of claim 3, wherein the flexible flap has a thickness of about 25 to 600  $\mu\text{m}$ .

30 23. The filtering face mask of claim 3, wherein the first layer has a thickness of about 5 to 700  $\mu\text{m}$ , and wherein the second layer has a thickness of about 5 to 100  $\mu\text{m}$ .

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24. The filtering face mask of claim 3, wherein the first layer has a thickness of about 10 to 600  $\mu\text{m}$ , and wherein the second layer has a thickness of about 10 to 85  $\mu\text{m}$ .

5 25. The filtering face mask of claim 3, wherein the first layer has a thickness of about 12 to 500  $\mu\text{m}$ , and wherein the second layer has a thickness of about 15 to 75  $\mu\text{m}$ .

10 26. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 85 liters per minute is less than about 50 Pascals.

15 27. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 85 liters per minute is less than about 40 Pascals.

28. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 85 liters per minute is less than about 30 Pascals.

15 29. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 30 Pascals.

20 30. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 30 Pascals.

31. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 25 Pascals.

25 32. The filtering face mask of claim 3, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 20 Pascals.

33. The filtering face mask of claim 3, wherein the pressure drop across the valve is about 5 to 50 Pascals between flow rates of 10 liters per minute and 85 liters per minute.

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34. The filtering face mask of claim 3, wherein the pressure drop across the valve is about 5 to 25 Pascals between flow rates of 10 liters per minute and 85 liters per minute.

5 35. The filtering face mask of claim 9 wherein the pressure drop is less than 5 Pascals at flow rates of 10 liters per minute.

10 36. The filtering face mask of claim 1, wherein the exhalation valve includes a third layer such that the flap has an ABA construction, wherein the B layer is stiffer than the A layers.

15 37. The filtering face mask of claim 1, wherein the exhalation valve includes a third layer such that the flap has an ABA' construction, wherein the B layer is stiffer than the A and A' layers, and wherein the A layer is located closer to the seal surface than the B layer.

20 38. The filtering face mask of claim 1, wherein the exhalation valve includes a third layer such that the flap has an ABC construction, wherein the B layer is stiffer than the A layers, and wherein the A layer is located closer to the seal surface than the B layer.

25 39. The filtering face mask of claim 1, wherein the exhalation valve includes a third layer such that the flap has an ABC construction, wherein the C layer is stiffer than the A and B layers, and is located closer to the seal surface than the A and B layers.

40. The filtering face mask of claim 1, wherein the first and second layers both contain polymer materials.

41. The filtering face mask of claim 3, wherein the first layer contains a rubber, and wherein the second layer contains polyethylene terephthalate or polycarbonate.

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42. The filtering face mask of claim 41, wherein rubber is a styrene-butadiene-styrene block copolymer.

5 43. The filtering face mask of claim 1, wherein the exhalation valve exhibits a valve efficiency of about 2 to 20 mW•g cm<sup>3</sup>/min.

10 44. The filtering face mask of claim 1, wherein the exhalation valve exhibits a valve efficiency of about 2 to 10 mW•g cm<sup>3</sup>/min.

15 45. A filtering face mask that comprises:

- (a) a mask body that is adapted to fit at least over the nose and mouth of a wearer to create an interior gas space when worn; and
- (b) an exhalation valve that is in fluid communication with the interior gas space, the exhalation valve comprising:

20 15 (i) a valve seat that comprises a seal surface and an orifice through which exhaled air may pass to leave the interior gas space; and

(ii) a flexible flap that is mounted to the valve seat such that the flap makes contact with the seal surface when the valve is in its closed position and such that the flap can flex away from the seal surface during an exhalation to allow exhaled air to pass through the orifice to ultimately enter an exterior gas space, the flexible flap comprising at least first and second juxtaposed layers, wherein at least one of the layers has a greater modulus of elasticity than the other layer.

25 46. The filtering face mask of claim 40, wherein the first layer is disposed closer to the seal surface than the second layer when the flap is positioned against the seal surface, and wherein the second layer has a greater modulus of elasticity than the first layer.

30 47. The filtering face mask of claim 46, wherein the first layer contacts the seal surface when the flap is positioned against the seal surface.

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48. The filtering face mask of claim 45, wherein the exhalation valve is mounted to the mask body.

49. The filtering face mask of claim 48, which is a negative pressure half-mask that has a fluid-permeable mask body that contains a layer of filter material.

50. The filtering face mask of claim 45, wherein the exhalation valve is a flapper-style exhalation valve.

10 51. The filtering face mask of claim 50, wherein the flapper-style exhalation valve has a planar seal surface.

15 52. The filtering face mask of claim 50, wherein the flexible flap is not pressed against the seal surface under neutral conditions.

53. The filtering face mask of claim 45, wherein the exhalation valve is in the form of a button-style valve.

20 54. The filtering face mask of claim 45, wherein the flexible flap includes a third layer that has substantially the same modulus of elasticity as the first layer.

55. The filtering face mask of claim 54, wherein the flexible flap exhibits symmetry with respect to the second layer, and wherein the second layer is stiffer than the first and third layers.

25 56. The filtering face mask of claim 45, wherein the second layer has a modulus of elasticity that is greater than the first layer, and wherein the first layer contacts the seal surface when the flap is positioned against the seal surface.

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57. The filtering face mask of claim 56, wherein the modulus of elasticity of the first layer is preferably about 0.15 to 10 megaPascals, and wherein the modulus of elasticity of the second layer is about 2 to  $1.1 \times 10^6$  megaPascals.

5 58. The filtering face mask of claim 56, wherein the modulus of elasticity of the first layer is preferably about 2 to 5 megaPascals, and wherein the modulus of elasticity of the second layer is about 200 to 11,000 megaPascals.

10 59. The filtering face mask of claim 58, wherein the second layer has a modulus of elasticity of 300 to 500 megaPascals.

15 60. The filtering face mask of claim 45, wherein the second layer has a greater modulus of elasticity than the first layer, and wherein the moduli ratio between the first layer and the second layer is less than 1.

15 61. The filtering face mask of claim 45, wherein the second layer has a greater modulus of elasticity than the first layer, and wherein the moduli ratio between the first layer and the second layer is less than 0.01.

20 62. The filtering face mask of claim 45, wherein the second layer has a greater modulus of elasticity than the first layer, and wherein the moduli ratio between the first layer and the second layer is less than 0.001.

25 63. The filtering face mask of claim 46, wherein the flexible flap has a thickness of about 10 to 2,000  $\mu\text{m}$ .

64. The filtering face mask of claim 46, wherein the flexible flap has a thickness of about 20 to 700  $\mu\text{m}$ .

30 65. The filtering face mask of claim 46, wherein the flexible flap has a thickness of about 25 to 600  $\mu\text{m}$ .

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66. The filtering face mask of claim 46, wherein the first layer has a thickness of about 5 to 700  $\mu\text{m}$ , and wherein the second layer has a thickness of about 5 to 100  $\mu\text{m}$ .

5 67. The filtering face mask of claim 46, wherein the first layer has a thickness of about 10 to 600  $\mu\text{m}$ , and wherein the second layer has a thickness of about 10 to 85  $\mu\text{m}$ .

10 68. The filtering face mask of claim 46, wherein the first layer has a thickness of about 12 to 500  $\mu\text{m}$ , and wherein the second layer has a thickness of about 15 to 75  $\mu\text{m}$ .

15 69. The filtering face mask of claim 46, wherein the pressure drop across the valve at a flow rate of 85 liters per minute is less than about 50 Pascals.

70. The filtering face mask of claim 46, wherein the pressure drop across the valve at a flow rate of 85 liters per minute is less than about 40 Pascals.

71. ~~69.~~ The filtering face mask of claim 46, wherein the pressure drop across the valve at a flow rate of 85 liters per minute is less than about 30 Pascals.

72. ~~70.~~ The filtering face mask of claim 46, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 30 Pascals.

73. ~~71.~~ The filtering face mask of claim 46, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 30 Pascals.

74. ~~72.~~ The filtering face mask of claim 46, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 25 Pascals.

75. ~~73.~~ The filtering face mask of claim 46, wherein the pressure drop across the valve had a flow rate of 10 liters per minute is less than 20 Pascals.

*P.J.J.* 74. The filtering face mask of claim 46, wherein the pressure drop across the valve is about 5 to 50 Pascals between flow rates of 10 liters per minute and 85 liters per minute.

5 75. The filtering face mask of claim 46, wherein the pressure drop across the valve is about 5 to 25 Pascals between flow rates of 10 liters per minute and 85 liters per minute.

10 76. The filtering face mask of claim 51 wherein the pressure drop is less than 5 Pascals at flow rates of 10 liters per minute.

15 77. The filtering face mask of claim 45, wherein the exhalation valve includes a third layer such that the flap has an ABA construction, wherein the B layer is stiffer than the A layers.

20 78. The filtering face mask of claim 45, wherein the exhalation valve includes a third layer such that the flap has an ABA' construction, wherein the B layer is stiffer than the A layers, and wherein the A layer is located closer to the seal surface than the B layer.

25 79. The filtering face mask of claim 45, wherein the exhalation valve includes a third layer such that the flap has an ABC construction, wherein the B layer is stiffer than the A layers, and wherein the A layer is located closer to the seal surface than the B layer.

80. The filtering face mask of claim 45, wherein the exhalation valve includes a third layer such that the flap has an ABC construction, wherein the C layer is stiffer than the A and B layers, and is located closer to the seal surface than the A and B layers.

81. The filtering face mask of claim 45, wherein the exhalation valve exhibits a valve efficiency of about 2 to 20 mW•g cm<sup>3</sup>/min.

*84* 82. The filtering face mask of claim 45, wherein the exhalation valve exhibits a valve efficiency of about 2 to 0 mW·g cm<sup>3</sup>/min.

*85* 83. An exhalation valve that comprises:

- 5 (i) valve seat that comprises a seal surface and an orifice through which a fluid may pass; and
- (ii) a flexible flap that is mounted to the valve seat such that the flap makes contact with the seal surface when the valve is in its closed position and such that the flap can flex away from the seal surface when an exhale flow stream is passing through the valve, the flexible flap comprising at least first and second 10 juxtaposed layers, wherein at least one of the layers is stiffer than the other.

*86* 84. The exhalation valve of claim 83, wherein the first layer is disposed closer 15 to the seal surface than the second layer when the valve is closed, and wherein the second layer is stiffer than the first layer.

*87* 85. An exhalation valve that comprises:

- (i) valve seat that comprises a seal surface and an orifice through which a fluid may pass; and
- (ii) a flexible flap that is mounted to the valve seat such that the flap makes contact with the seal surface when the valve is in its closed position and such that the flap can flex away from the seal surface when an exhale flow stream is passing through the valve, the flexible flap comprising at least first and second 20 juxtaposed layers, wherein at least one of the layers has a greater modulus of elasticity than the other.

*88* 86. The exhalation valve of claim 85, wherein the first layer is disposed closer 25 to the seal surface than the second layer when the valve is closed, and wherein the second layer has a greater modulus of elasticity than the first layer.

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87. An inhalation valve that comprises:

- (i) valve seat that comprises a seal surface and an orifice through which a fluid may pass; and
- (ii) a flexible flap that is mounted to the valve seat such that the flap makes contact with the seal surface when the valve is in its closed position and such that the flap can flex away from the seal surface when an inhale flow stream is passing through the valve, the flexible flap comprising at least first and second juxtaposed layers, wherein at least one of the layers is stiffer than the other.

10 88. The inhalation valve of claim 87, wherein the first layer is disposed closer to the seal surface than the second layer when the valve is closed, and wherein the second layer is stiffer than the first layer.

15 89. An inhalation valve that comprises:

- (i) valve seat that comprises a seal surface and an orifice through which a fluid may pass; and
- (ii) a flexible flap that is mounted to the valve seat such that the flap makes contact with the seal surface when the valve is in its closed position and such that the flap can flex away from the seal surface when an inhale flow stream is passing through the valve, the flexible flap comprising at least first and second juxtaposed layers, wherein at least one of the layers has a greater modulus of elasticity than the other.

20 90. The inhalation valve of claim 89, wherein the first layer is disposed closer to the seal surface than the second layer when the valve is closed, and wherein the second layer has a greater modulus of elasticity than the first layer.

25 91. A filtering face mask that comprises the inhalation valve of claim 87.

30 92. A filtering face mask that comprises the inhalation valve of claim 89.